<H1> Summary

The effectiveness of transcutaneous electrical nerve stimulation (TENS) for pain relief has been challenged. This article evaluates systematic review findings and demonstrates that studies using appropriate TENS technique and dosage are more likely to demonstrate efficacy. Therefore, it seems reasonable to continue to use TENS.

[45 words]

<H1> Keywords

Transcutaneous electrical nerve stimulation (TENS), Pain, Efficacy, Randomised controlled clinical trial, Systematic review and meta-analysis

<H1> Short Title

Efficacy of TENS

<H1> Introduction

The use of electrical stimulation of the skin for symptomatic relief of pain is an age-old technique with the ancient Egyptians (circa 2500 B.C.) and the ancient Romans (circa 15 A.D.) using live electric fish placed on the skin to relieve pain for various ailments (Gildenberg, 2006). Nowadays, electrical stimulation of the skin is achieved using battery operated devices that generate pulsed currents that are delivered across the intact surface of the skin using self-adhering electrodes and lead wires (Figure 1). The technique is called transcutaneous electrical nerve stimulation (TENS). The goal of TENS is to stimulate peripheral nerves as this has been shown to reduce transmission of pain-related information in a manner similar to rubbing the skin (Johnson and Bjordal 2011). Therefore, TENS is used to “electrically rub pain away”.

[Figure 1 - TENS and accessories]

TENS is used as an adjunct to core treatment for symptomatic relief of inflammatory, neuropathic and musculoskeletal pain. TENS can be used as a stand-alone treatment for mild to moderate pain and in combination with medication for moderate to severe pain. It is popular with patients and practitioners because it is safe, non-invasive, inexpensive, easy to self-administer, and pain relief is rapid in onset. There is no potential for toxicity or overdose so patients can titrate dosage as needed. TENS devices and accessories (lead-wires, electrodes and batteries) can be purchased at pharmacies or via the internet without prescription for £15 to £100 GBP. TENS may be prescribed by health care professionals depending on local policy. Nurses, midwifes and physiotherapists often support patients in the use of TENS.

Uncertainty about the usefulness of TENS has persisted for decades due in part to varied recommendations by expert panels. For example, the UK National Institute for Health and Clinical Excellence (NICE) recommend that TENS should be offered for short-term relief of osteoarthritic knee pain (National Institute for Health and Clinical Excellence 2008), rheumatoid arthritis of the hand (National Institute for Health and Clinical Excellence 2009a) and musculoskeletal pain secondary to multiple sclerosis (National Institute for Health and Clinical Excellence 2003) but not for persistent non-specific low back pain (National Institute for Health and Clinical Excellence 2009b), pain during established labour (National Institute for Health and Clinical Excellence 2007) or angina (National Institute for Health and Clinical Excellence 2011). Recently, the Centers for Medicare and Medicaid Services in the USA, decided that there was insufficient strong evidence that TENS was effective for chronic low back pain and discontinued insurance coverage until evidence from an suitably robust randomized controlled clinical trial (RCT) showed otherwise (Jacques et al 2012). The aim of this article is to determine whether there is a case to support the continued use of TENS by critically reviewing clinical research and exploring reasons for inconsistency in clinical guidelines.

<H1> Principles and practice of TENS

Many myths and opinions remain about how best to use TENS in clinical practice, fueled in part by the assortment of combinations of electrical output characteristics available on even the simplest of TENS devices (Figure 2). A detailed description of technique can be found by Johnson (2012) and in a forthcoming textbook (Johnson 2014). A brief summary of appropriate TENS technique is provided here.

[Insert Figure 2 here]

<H2> TENS techniques

Two TENS techniques are commonly employed in practice.

a) Conventional TENS using *high frequency, low intensity* currents to generate a strong, non-painful TENS sensation without muscle contractions at the site of pain or in related dermatomes
b) Acupuncture-like TENS (AL-TENS) using *low frequency, high intensity* currents to generate non-painful phasic muscle contractions (twitching) at the site of pain or in related myotomes

Conventional TENS is the method of choice in most instances, with AL-TENS reserved for patients who do not respond to conventional TENS. There are some circumstances when AL-TENS may be selected before conventional TENS including the presence of altered skin sensitivity, radiating pain, pain arising from deep structures and widespread or multiple site pain. AL-TENS requires a greater understanding of physiological principles to administer appropriately. Patients taking regular opioid medication may respond less well to AL-TENS because the actions of AL-TENS are mediated via the release of endogenous opioids and animal studies have found a role for spinal opioid receptors in the development of tolerance to TENS analgesia (Chandran and Sluka, 2003).

Appropriate electrode positioning and sufficiently strong TENS is critical to success. For both techniques electrodes should be placed on healthy innervated skin where sensation is intact. A systematic trial and error approach is taken to find optimal positions. For conventional TENS electrodes should be positioned so that the TENS sensation covers the painful area and this is usually achieved by applying electrodes on the outer margins of the pain (Figure 3). This may not be possible when

- it is difficult to attach electrodes to body parts e.g. hands, feet, body creases
- there is altered skin sensation or a skin lesion over the site of pain
- a body part is absent e.g. phantom limb pain

In these instances electrodes are placed over the main nerves proximal to the site of pain, or close to vertebrae of spinal segments, over contralateral dermatomes, over acupuncture points (acu-TENS) and over trigger points.

[Insert Figure 3 here]

A sufficiently strong TENS sensation is critical for the success of conventional TENS (Moran et al 2011). To achieve this patients are instructed to increase the pulse amplitude of the currents to attain a strong yet non-painful TENS sensation. There is insufficient consistent evidence from clinical studies to support prescribing other electrical characteristics including pulse frequencies, durations and patterns so selection is made by the patient according to what is most comfortable for them at that moment in time. Repeated daily use of TENS may cause analgesic tolerance which may be overcome by increasing the intensity of TENS each day or by changing the electrical characteristics of stimulation.

There are no reliable predictors of success so any type of pain may respond to TENS. It is important to conduct a supervised trial to screen for suitability and to familiarize the patient with safe and appropriate technique including selecting appropriate electrode positions and electrical characteristics. Generally, TENS can be used with little risk for most patients but if there is concern then the situation must be discussed with the patient and their physician and all risks and consequences disclosed.

<H2> Contraindications and precautions

Safety guidelines have been published by professional bodies to guide clinical judgments about the suitability of TENS (e.g. the Australian Physiotherapy Association (Robertson et al 2001), the Chartered Society of Physiotherapy in the United Kingdom (Chartered Society of Physiotherapy 2006), and the Canadian Physiotherapy Association (Houghton et al 2010). Manufacturers identify cardiac pacemakers, pregnancy, and epilepsy as contraindications because it may be difficult from a medico-legal perspective to exclude TENS as contributing to a problem. However, there is limited research evidence directly linking TENS to adverse events in these cases so some practitioners have used TENS providing it is not administered over the area of concern and the progress of the patient is monitored carefully.

Before using TENS it is important to check whether the patient has an implant or external attachment (e.g. drainage system). If so, it is necessary to ascertain whether electrical currents from TENS could interfere with operation of the implant or cause mechanical stresses in tissues by TENS-induced muscle contraction or blood vessel constriction or dilatation. For example, an implanted electrical device may need to discriminate between true electrical activity from biological tissue such as the heart and the electrical current generated by the TENS device. If TENS caused a malfunction of such a device it could be life-threatening. For this reason TENS is contraindicated for patients with cardioverter defibrillators because there is strong evidence that TENS causes interferes with their functioning. TENS is also contraindicated for cardiac pacemakers, although Carlson et al (2009) have used TENS for individuals with cardiac pacemakers. They have developed a ECG testing and monitoring procedure performed during the first application of TENS and recommended that patients are contraindicated if it is not possible for the pacemaker rate to override a spontaneous tachycardia or if there is an absence of ventricular inhibited (ventricular demand, VVI) pacing of at least 40 bpm. Cardiologists must be involved in all decisions about the possibility of using TENS in these circumstances.

TENS may be used as part of a rehabilitation package after joint replacement surgery. There are no known reports of adverse events for TENS although a mild skin burn has been reported during the use of interferential current therapy (a TENS-like device) over a metal implant following unicompartmental knee arthroplasty (Ford et al 2005). When using TENS for pain associated with stents, percutaneous drainage systems, and central venous catheters it is advisable that low-intensity conventional TENS without muscle contractions is used so that mechanical stresses to surrounding tissue are kept at an absolute minimum. Careful monitoring is critical when using TENS in all of these situations.

TENS should not be administered over the abdomen in pregnancy, the head in epilepsy, or over areas where there is deep vein thrombosis, recent haemorrhage or damaged skin, including skin with altered sensitivity. TENS should not be delivered over areas where there is active malignancy for patients with ‘treatable’ tumours in acute oncology settings because the effect of TENS on cancerous tissue is not known. However, TENS may be used in palliative setting under the supervision of a palliative care specialist. TENS should not be used on irradiated skin in the immediate weeks after radiotherapy.

Hazardous electrode sites include the anterior neck over the carotid sinus, transorbital (i.e. across the eyes), transthoracic (i.e. using electrodes on the front and back of the chest) and transcranial (i.e. using electrodes on the right and left temple)(Figure 4).

[Insert Figure 4 here]

The importance of educating patients, investigators and practitioners about appropriate TENS technique and to put in places processes to monitor adherence cannot be over emphasised. Recently, an observational study found that patients with chronic low back pain did not follow instructions from research investigators about how often and for how long to self-administer TENS at home (Pallett et al 2013). Furthermore, pain is often used as the primary outcome, although it is amorphous and notoriously difficult to measure reliably. Therefore, treatment goals should be framed as measureable functional outcomes that can monitor progress and can be verified with quantifiable changes in behaviour and quality of life.

<H1> Evidence for the effectiveness of TENS

Published research literature on TENS is vast with the number of hits increasing on a yearly basis (Figure 5). An unfiltered search in PubMed on 18 October 2013 using the Medical Subject Header (MeSH) 'transcutaneous electric nerve stimulation' yielded 6039 hits. Most of the clinical research comprises cohort studies, case-series and clinical trials without controls and the majority of these studies find that TENS reduces pain. However, the lack of suitable control groups means that observations of pain relief from TENS may be contaminated by expectation of treatment success and non-specific effects of the practitioner-patient encounter. Randomized controlled clinical trials (RCTs) are studies that attempt to remove bias associated with non-specific treatment effect so the effect of the "active ingredient" of the treatment can be evaluated (i.e. efficacy). Often RCTs compare a treatment with a placebo that has no active ingredient but is indistinguishable from the treatment. This enables investigators to conceal (blind) the treatment and placebo from trial participants and outcome assessors, reducing biases associated with the expectation that a treatment will be beneficial.

[Insert Figure 5 here]

Randomized placebo-controlled clinical trials of TENS determine whether electrical currents used during TENS contribute to clinical outcome. They answer the question "Do you need to put batteries in the TENS device to get beneficial effects?" A PubMed search on 18 October 2013 limited to randomized controlled clinical trials yielded 1006 hits. Systematic reviews are used to identify, appraise and synthesize the findings of RCTs and they may include meta-analyses that combine (pool) data from each RCT to estimate the overall size of the treatment effect. Systematic reviews and meta-analyses of RCTs are top of the hierarchy of clinical research evidence when determining efficacy and/or effectiveness.

The first systematic reviews on TENS were published in 1996 and they challenged the belief at the time that TENS was efficacious for acute and chronic pain (Carroll et al 1996, Reeve et al 1996) (Table 1). Since then there has been a proliferation of systematic reviews, many using methodology of the Cochrane collaboration (Cochrane reviews). Many systematic reviews have found that research is either inconclusive or conflicting, highlighting the difficulty of making sense of the evidence.

[Insert Table 1 here]

<H2> TENS for Acute Pain

The most recent Cochrane review on TENS as a sole treatment for acute pain (<12 weeks) in adults was inconclusive (Walsh et al 2009). Many RCTs were excluded from the review because it was impossible to isolate the effect of TENS because participants were combining other treatments with TENS.

<H3> TENS for Post-operative Pain

The first systematic review on TENS for post-operative pain found TENS to be superior to placebo in 17 of 19 non-RCTs but no different to placebo in 15 of 17 RCTs (Carroll et al 1996). It was concluded that TENS was not effective and that non-RCTs overestimated treatment effects, although the effects of TENS may have been masked in part by participants also consuming analgesic medication. The first meta-analysis on TENS was conducted in 2003 and found that TENS reduced post-operative consumption of analgesic medication to a greater extent than placebo TENS (Bjordal et al 2003). Larger effects were observed in the 11 RCTs that used adequate TENS technique defined as ''strong, definite, sub noxious, maximal tolerable… within or close to site of pain" compared with 9 RCTs that did not. More recently, evidence from systematic reviews suggests that TENS in combination with analgesic medication is superior to placebo TENS in combination with analgesic medication for the relief of thoracotomy or post-sternotomy pain (Freynet and Falcoz 2010, Sbruzzi et al 2012)(Table 1).

<H3> TENS for Labour Pain

Despite widespread use of TENS for pain during childbirth, systematic reviews have failed to find conclusive evidence of TENS efficacy, although there is tentative evidence that women receiving TENS are more “satisfied” than those receiving placebo (Bedwell et al 2011, Carroll et al 1997; Dowswell et al 2009, Mello et al 2011, Reeve et al 1996). RCT findings are conflicting with most RCTs not evaluating TENS in the early stages labour where it is more likely to be effective.

<H3> TENS for Dysmenorrhoea, Angina and other acute pains

There is weak evidence from a Cochrane review that high but not low frequency TENS was superior to placebo for primary dysmenorrhoea (Proctor et al 2003) and tentative evidence from RCTs with small samples sizes that TENS reduces angina pectoris-like chest pain and pain from lacerations, fractures, hematomas, contusions and dental procedures (de Vries et al 2007).

<H1> TENS for Chronic Pain

In 2008, Claydon and Chesterton (2008) evaluated six systematic reviews on TENS for chronic low back pain, osteoarthritis of the knee, rheumatoid arthritis of the hand, chronic musculoskeletal pain, and miscellaneous chronic pain. They found evidence in three reviews that TENS was superior to placebo and that higher intensities of TENS generated greater pain relief. The most recent Cochrane review for chronic pain was inconclusive (Nnoaham and Kumbang 2008) and the most recent Cochrane review on TENS for cancer pain found insufficient RCTs to make a meaningful judgment on efficacy (Hurlow et al 2012).

<H2> TENS for Neuropathic Pain

There are few RCTs on TENS for neuropathic pain with no Cochrane reviews published to date. Systematic reviews provide tentative evidence that TENS relieves peripheral neuropathy (Jin et al 2010, Dubinsky and Miyasaki 2010), post-stroke pain (Price and Pandyan 2001) and spinal cord injury (Fattal et al 2009). There were insufficient RCTs to make a judgment for post-amputation pain (Mulvey et al 2010), although case-series are promising (Mulvey et al 2012). In 2007, the European Federation of Neurological Societies Task Force for neurostimulation therapy for neuropathic pain recommended that TENS should be offered as a preliminary or add-on therapy for neuropathic pain, although evidence that TENS was superior than placebo was weak (Cruccu et al 2007).

<H2> TENS for Chronic Musculoskeletal Pain

To date the largest meta-analysis on TENS evaluated efficacy for chronic musculoskeletal pain and provided strong evidence that pain relief during TENS was three times that seen by placebo (Johnson and Martinson 2007). Cochrane reviews on TENS for neck pain (Kroeling et al 2009), chronic, recurrent headache (Bronfort et al 2004) and rheumatoid arthritis of the hand (Brosseau et al 2003), provide only weak evidence for efficacy. RCTs with small sample sizes offer tentative evidence of efficacy for fibromyalgia (Lauretti et al 2013, Carbonario et al 2013, Lofgren and Norrbrink 2009, Mutlu et al 2013), myofascial pain syndrome (Rodriguez-Fernandez et al 2011, Gemmell and Hilland 2011, Hou et al 2002) and epicondylitis (Weng et al 2005). Recently, a well-designed RCT found that TENS did not provide additional pain relief when administered as an adjunct to primary care management for tennis elbow, although this may have been due in part to participants not following instructions for optimal self-administered TENS treatment (Chesterton et al 2013).

<H3> TENS for Osteoarthritis

A meta-analysis of 7 RCTs using adequate TENS technique found that TENS was superior to placebo with reductions in pain of 22.2 mm (95% confidence interval = 18.1 to 26.3) on a 100 mm visual analogue scale (Bjordal et al 2007). The most recent Cochrane review of TENS for osteoarthritis of the knee(s) included a meta-analysis of 16 RCTs and found that TENS (including interferential current therapy) reduced pain by 21mm compared with control groups (Rutjes et al 2009). However, when small methodologically weak RCTs were removed from the analysis the size of pain relief became negligible and the reviewers decided that evidence was inconclusive. Recently, a well-designed RCT found that TENS conferred no additional benefits to education and exercise (Palmer et al 2013).

<H3> TENS for Chronic Low Back Pain

The most recent Cochrane review on TENS for low back pain was inconclusive (Khadilkar et al 2008) and the most recent meta-analysis found no difference between TENS and placebo, although there were too few RCTs to make a reliable judgment (van Middelkoop et al 2011). Many systematic reviews on TENS for chronic low back pain have been conducted as part of projects to develop clinical practice guidelines with claims that TENS is efficacious (Airaksinen et al 2006, Poitras and Brosseau 2008), not efficacious (Dubinsky and Miyasaki 2010, Jacques et al 2012, Philadelphia Panel

2001) or of unknown efficacy (Chou and Huffman 2007, National Institute for Health and Clinical Excellence 2009b).

<H1> Dangers of accepting clinical practice guidelines on TENS on face value

Clinical practice recommendations on the use of TENS for chronic low back pain have a major impact on the perception of TENS treatment in general. In the UK, NICE recommended “Do not offer Transcutaneous electric nerve stimulation (TENS) [for early management of persistent non-specific low back pain]” (National Institute for Health and Clinical Excellence 2009b: p133) and in the USA, the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology stated that “Transcutaneous electric nerve stimulation (TENS) is not recommended for the treatment of chronic low back pain (Level A [evidence])” (Dubinsky and Miyasaki 2010: p173). In 2012, the Centers for Medicare and Medicaid Services in the USA concluded that “TENS is not reasonable and necessary for the treatment of chronic low back pain” and discontinued insurance coverage unless beneficiaries were enrolled on a RCT (Jacques et al 2012). Yet in the same year the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine recommended that “TENS should be used as part of a multimodal approach to pain management for patients with chronic back pain and may be used for other pain conditions (e.g. neck and phantom limb pain).” (American Society of Anesthesiologists 2010: p816).

The contradictory nature of evidence and professional and regulatory body recommendations creates uncertainty for practitioners. Furthermore, the fact that there are more systematic reviews than RCTs on TENS for chronic low back pain should raise serious concern about the evidence on which recommendations are based. A critical evaluation by the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology provides an insight to methodological shortcomings in many systematic reviews on TENS. The Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology concluded that “TENS is established as ineffective [for chronic low back pain]” (Dubinsky and Miyasaki, 2010: p174). They claimed that this was based on Level A evidence consisting of two ‘good quality’ RCTs. Interestingly, only 114 participants received TENS and 87 received placebo (no current) TENS in these two RCTs. One of the RCTs (Deyo et al 1990) was criticized at the time of publication because TENS technique and dose were considered to be inadequate. There was concurrent use of hot packs in all treatment arms that may have masked the effects of TENS and participants in the placebo TENS group reported improvements in pain that lasted up to 2 months post intervention which seemed unreasonably efficacious. Participants were recruited via newspaper advertising and likely to be treatment resistant and not representative of chronic low back patients in general. Aetiologies were varied including neurological deficits (12%), nerve-root irritation (16%) and self-reported history of arthritis (30%). The other RCT found no differences between TENS and placebo TENS for chronic low back pain associated with multiple sclerosis although the investigators argued that clinically important improvements occurred during TENS but not placebo (Warke et al 2006). Participants in both groups had access to additional analgesics.

The Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology also evaluated evidence for TENS and diabetic neuropathy and concluded that "TENS is probably effective in treating painful diabetic neuropathy (2 Class II studies)" (Dubinsky and Miyasaki, 2010: p173). They recommended that "TENS should be considered in the treatment of painful diabetic neuropathy (Level B [evidence])" (Dubinsky and Miyasaki, 2010: p173) although this was based on only 31 participants receiving TENS and 24 placebo TENS. Johnson and Walsh (2010) critiqued the assessment and summarized the situation as follows: "It seems unreasonable that the effectiveness of TENS, and subsequent clinical recommendations, can be established from studies with so few participants" (Johnson and Walsh 2010: p314).

Basing clinical recommendations on such small data sets is not unique to TENS. (Machado et al 2009) conducted a review of 34 treatments (76 RCTs) for non-specific chronic low back pain with total sample populations relatively low for most treatments including electroacupuncture (25 participants: 1 RCT), acupuncture (149 participants: 4 RCTs), exercise (204: 3 RCTs), antidepressants (217 participants: 4 RCTs) and nerve blocks (17 participants: 1 RCT). Interestingly, the efficacy of TENS (178 participants: 4 RCTs) compared favourably with other treatments including muscle relaxants (820 participants: 9 RCTs) and non-steroidal anti-inflammatory drugs (1349 participants: 7 RCTs), with a 10-20% reduction in pain from baseline.

A review of the methodological quality of RCTs on TENS revealed that under-dosing and the use of inadequate TENS technique was common in RCTs (Bennett et al 2011). The reviewers developed methodological criteria and operational procedures to deliver an 'ideal' RCT on TENS and it is hoped that this will lead to improved design of RCTs in the future and to a more robust evidence base.

<H1> Should TENS still be used?

This review demonstrates that recommendations from professional and government bodies that TENS should not be offered for certain painful conditions are based on a lack of good quality evidence to make a judgement about efficacy rather than good quality evidence that TENS is not effective. Meta-analyses of RCTs using appropriate TENS technique and dosage provide strong evidence that TENS is superior to placebo TENS for chronic musculoskeletal pain and for post-operative pain, and moderate evidence that TENS is efficacious for neuropathic pain. In addition the general consensus from clinical experience is that TENS helps patients manage their pain. Therefore, it seems reasonable that nurses are able to offer TENS as an adjunct to core treatment for painful conditions especially as it is inexpensive and has a favourable safety profile compared with long term medication. Whether the costs of supplying TENS devices and accessories is covered by health care providers or patients is a matter for policy makers. Nevertheless, no matter how patients obtain TENS devices and accessories it is critical that nurses are in a position to educate patients about safe and appropriate TENS technique including the need for patients to regularly self-administer TENS.

Word count: 4118 words

<H1> References

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<H1> Figure Legends

Figure 1

TENS and accessories used to manage chronic low back pain

Figure 2

Output characteristics of TENS devices commonly used in practice

Figure 3

Commonly used electrode positions for conventional TENS

Figure 4

Hazardous electrode positions for TENS. Shaded areas show general area of hazard where electrodes should never be positioned for certain conditions. ⊘ signifies dangerous electrode combinations.

Figure 5

Number of 'hits' by year for an unfiltered PubMed search using the Medical Subject Header (MeSH) 'transcutaneous electric nerve stimulation' on 18 October 2013. [search string: "transcutaneous electric nerve stimulation"[MeSH Terms] OR ("transcutaneous"[All Fields] AND "electric"[All Fields] AND "nerve"[All Fields] AND "stimulation"[All Fields]) OR "transcutaneous electric nerve stimulation"[All Fields])]

<H1> Tables

Table 1

Summary of systematic reviews published in peer reviewed journals evaluating TENS for pain

Reference	Data set for TENS and Method of Analysis	Reviewers' conclusion	Comment
Acute Pain			
Walsh et al (2009)	Acute pain (miscellaneous) 12 RCTs (919 patients) Descriptive analysis (Cochrane review)	Evidence inconclusive	Low quality studies with small sample sizes
Carroll et al (1996)	Postoperative pain (miscellaneous) 17 RCTs (786 patients) Descriptive analysis	Evidence of no effect	Patients allowed free access to analgesic medication in some RCTs
Bjordal et al (2003)	Postoperative analgesic consumption 21 RCTs (964 patients) Meta-analysis	Evidence of effect	Demonstrated that adequate TENS technique critical for effect
Freynet and Falcoz (2010)	Post-thoracotomy pain 9 RCTs (645 patients) Descriptive analysis	Evidence of effect as adjuvant but not as standalone treatment	Most studies low quality studies with small sample sizes TENS > placebo as adjuvant to opioids for acute post-thoracotomy pain
Sbruzzi et al (2012)	Post thoracic surgery pain 11 studies	Evidence of effect	TENS with medication > placebo with medication for thoracotomy and sternotomy
Carroll et al (1997)	Labour pain 10 RCTs (877 patients) Descriptive analysis	Evidence of no effect	Comparison groups consisted of active and inactive interventions. Patients allowed free access to analgesic medication in some RCTs

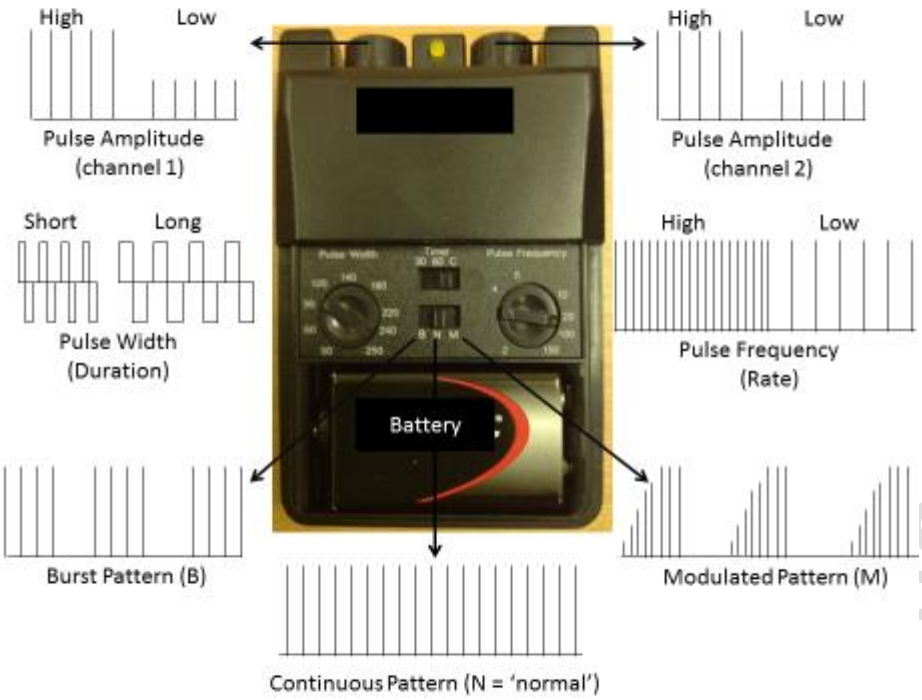
Dowswell et al (2009)	Labour pain 19 RCTs (1671 patients) Descriptive analysis (Cochrane review)	Evidence inconclusive	Low quality studies
Bedwell et al (2011) Update of Dowswell et al (2009)	Labour pain 14 studies (1256 women)	Evidence inconclusive	Women receiving TENS to acupuncture points were less likely to report severe pain Women using TENS would use it again in a future labour
Mello et al (2011)	Labour pain 9 studies (1076 women)	Evidence of no effect	TENS = placebo for pain relief and the need for additional analgesia Women using TENS would use it again in a future labour
Proctor et al (2003)	Primary dysmenorrhoea 7 RCTs, (213 patients) Descriptive analysis (Cochrane review)	Evidence of effect but only for high frequency TENS	Low quality studies with small sample sizes
McIntosh and Hall (2011)	Acute low back pain 1 systematic review (Machado et al 2009)	Insufficient evidence to judge	Evidence was of low quality
Abou-Setta et al (2011)	Pain after hip fracture 2 studies on TENS	Insufficient evidence to judge	Only 2 studies on TENS
Chronic Pain			
Nnoaham and Kumbang (2008)	Chronic pain (miscellaneous) 25 RCTs (1281) Descriptive analysis (Cochrane review)	Evidence inconclusive	Low quality studies with small sample sizes and possibility of under dosing TENS

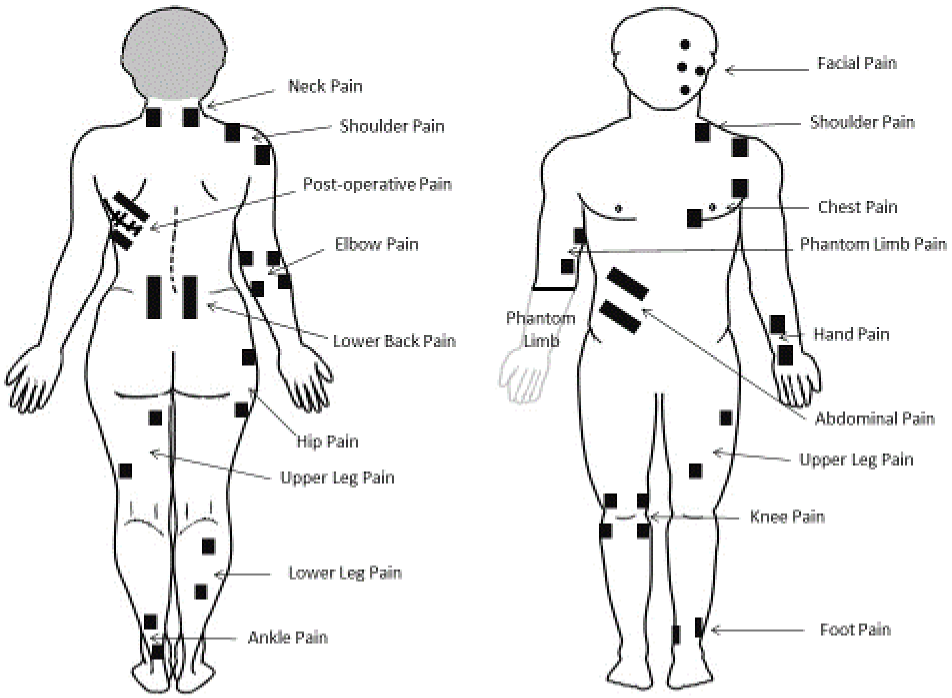
Johnson and Martinson (2007)	Chronic musculoskeletal pain (miscellaneous) 32 RCTs on TENS, 6 RCTs on percutaneous electrical nerve stimulation (1227 patients) Meta-analysis	Evidence of effect	Criticised for using multiple diseases creating heterogeneity
Khadilkar et al (2008)	Chronic low back pain (miscellaneous) 3 RCTs (197 patients) Descriptive analysis (Cochrane review)	Insufficient evidence to judge	Low quality studies with small sample sizes and possibility of under dosing TENS 2 RCTS suggested TENS did not improve back-specific functional status
Poitras and Brosseau (2008)	Chronic low back pain (miscellaneous) 6 RCTs (375 patients) Descriptive analysis	Evidence of effect	Low quality studies with small sample sizes
Machado et al (2009)	Non-specific low back pain (acute and chronic) 4 RCTS (178 patients), 2 acute, 2 chronic	Evidence of effect	Low quality studies with small sample sizes Insufficient evidence to judge
Chou (2010)	Chronic low back pain (miscellaneous) 1 systematic review (Khadilkar et al 2008) and 1 additional RCT	Evidence inconclusive	Available evidence very low quality. RCTs heterogeneous in design and TENS technique
Dubinsky and Miyasaki (2010)	Chronic low back pain (Painful neurological conditions) 2 RCTs (201 patients) Descriptive analysis	Evidence of no effect	Small sample sizes and possibility of under dosing TENS Insufficient evidence to judge

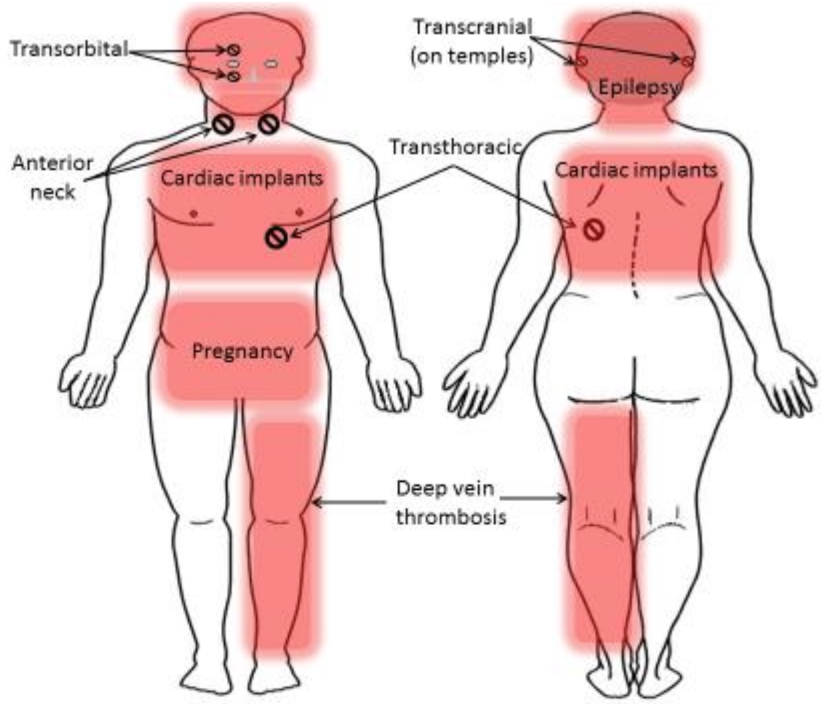
Rutjes et al (2009)	Knee osteoarthritis 18 RCTs (275 patients) Descriptive analysis (Cochrane review)	Evidence inconclusive	Low quality studies with small sample sizes with some RCTs not using standard TENS device
Bjordal et al (2007)	Knee osteoarthritis 7 RCTs (414 patients) Meta-analysis	TENS effective in short term	Accounted for adequate TENS technique in analysis
Brosseau et al (2003)	Rheumatoid arthritis 3 RCT (78 patients) Meta-analysis (Cochrane review)	Evidence of effect	Low quality studies with small sample sizes
(Robb et al (2008)	Cancer pain and its treatment 2 RCTs (64 participants) Descriptive analysis (Cochrane review)	Insufficient evidence to judge	Low quality studies with small sample sizes and possibility of under dosing TENS
Hurlow et al (2012) Update of Robb et al (2008)	Cancer pain and its treatment 3 studies (88 participants) Descriptive analysis (Cochrane review)	Insufficient evidence to judge	Low quality studies with small sample sizes and possibility of under dosing TENS
Kroeling et al (2009)	Neck disorders (whiplash associated disorders and mechanical neck disorders) 7 RCTs on TENS (88 patients) Descriptive analysis (Cochrane review)	Evidence of effect but low quality studies	Low quality studies with small sample sizes and possibility of under dosing TENS. Included any surface electrical stimulation (ES) including microcurrent devices Insufficient evidence to judge
Bronfort et al (2004)	Chronic headache 3 RCTs	Evidence inconclusive	Low quality studies with small sample sizes and possibility of under dosing TENS

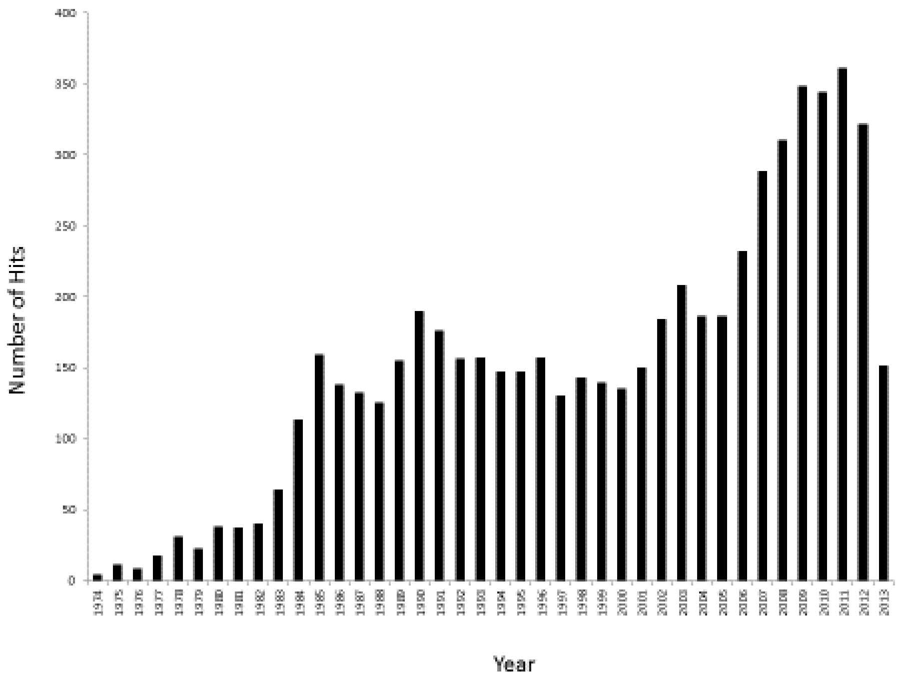
	Descriptive analysis (Cochrane review)		Insufficient evidence to judge
Jin et al (2010)	Painful diabetic neuropathy 3 RCTs (78 patients) Meta-analysis	Evidence of effect	Low quality studies with small sample sizes. Used non-standard TENS devices Insufficient evidence to judge
Dubinsky and Miyasaki (2010)	Painful diabetic neuropathy (Painful neurological conditions) 3 RCTs (2 RCTs used in evaluation 55 patients) Descriptive analysis	Evidence of effect	Low quality studies with small sample sizes Insufficient evidence to judge
Pieber et al (2010)	Painful diabetic neuropathy 15 studies 3 RCTs + 1 retrospective analysis TENS (n=130 participants)	Evidence of effect (Level B)	TENS > placebo three large studies and one small study Studies used H-Wave therapy not TENS
Price and Pandyan (2000)	Post-stroke shoulder pain 4 RCTs (170 patients) of any surface electrical stimulation (Cochrane review)	Evidence inconclusive	Low quality studies with small sample sizes and possibility of under dosing TENS 2RCTs used TENS to produce muscle contractions Insufficient evidence to judge
Cruccu et al (2007)	Various neuropathies 9 controlled trials (200 patients) Descriptive analysis	Evidence of effect	Low quality studies with small sample sizes Insufficient evidence to judge
Mulvey et al (2010)	Post amputation pain 0 RCTs (Cochrane review)	No evidence available	Insufficient evidence to judge


Self-adhering
electrodes
TENS device
Lead-wire
(disconnected from TENS device)


High
Low
Pulse Amplitude
(channel 1)
High
Low
Pulse Amplitude
(channel 2)
[redacted]
Short
Long
Pulse Width
(Duration)
High
Low
Pulse Frequency
(Rate)
B N M
Battery
Burst Pattern (B)
Modulated Pattern (M)
Continuous Pattern (N = 'normal')


Neck Pain
Shoulder Pain
Post-operative Pain
Elbow Pain
Lower Back Pain
Hip Pain
Upper Leg Pain
Lower Leg Pain
Ankle Pain
Facial Pain
Shoulder Pain
Chest Pain
Phantom Limb Pain
Phantom Limb
Hand Pain
Abdominal Pain
Upper Leg Pain
Knee Pain
Foot Pain


Transorbital
Anterior
neck
Cardiac implants
Pregnancy
Transcranial
(on temples)
Epilepsy
Transthoracic
Cardiac implants
Deep vein
thrombosis


Number of Hits
Year